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DEVELOPMENT OF A CLOSED CIRCUIT TV BOREHOLE PROBE

Contract H0308041
Design Engineering Laboratories, Inc.

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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16. Abstract (Limit: 200 words)

This report describes a 4-inch diameter borehole probe which contains a low light level TV camera, magnetic compass, light illumination source, bottom/water detector sensor and a pointing angle sensor. The camera viewing angle is at a right angle to the probe's body.

All data from the sensor is multiplexed into the closed circuit camera video for transmission on a single 50 ohm coaxial cable to a surface control unit. Likewise control of the probe's power, zoom lens, focus, panning and aperture is accomplished via a down-link multiplexed on the same cable.

17. Document Analysis a. Descriptors

TV Borehole Probe, Downhole Data Link, Borehole TV Camera, Mulitplexed Data Link, Magnetic Compass Sensor, Downhole TV Tool

b. Identifiers/Open-Ended Terms

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FOREWARD

This report was prepared by Design Engineering Laboratories, Inc. under USBM Contract number H0308041. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PSMRC with Mr. Merle Bowswer acting as the original Technical Project Officer subsequently replaced by Mr. James Means. Mr. Mike Nowicki was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period December 1979 to September 1984. This report was submitted by the authors on September 1, 1984.

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1. INTRODUCTION

This document presents the final report on the development of a "Closed Circuit TV Borehole Probe" which utilizes a low light level TV camera magnetic compass and a multiplex system to transmit video and data over a 1000 foot coaxial cable to an uphole control unit.

1.1 Background

Under this contract Design Engineering Laboratories (DEL) was given the task of developing a probe based on modifying an existing Bureau of Mines TV probe design to accomplish the following:

a. Provide additional space for an improved low light level TV camera which was procured from Westinghouse and supplied to DEL by the Bureau of Mines.

b. Add zoom lens capability.

c. Add a magnetic compass and relative pointing angle sensor.

d. Provide a multiplexed uplink/downlink capability to permit transmission of all video/sensor data and camera/probe controls on a single coaxial cable. This permits substantial reduction in the diameter and weight of the 1000 foot cable used with the probe.

Drawings of the existing probe were supplied to DEL to utilize as the baseline design for the new probe. To minimize risk, minimum modifications to the existing design were desired. Hence most of the basic mechanical and packaging concepts were retained. The new probe was made 0.5 inches larger in diameter to provide additional space for the camera zoom lens.

1.2 Probe Configuration

Figure 1 shows the overall probe configuration which consists of five major modules or assemblies. These are:

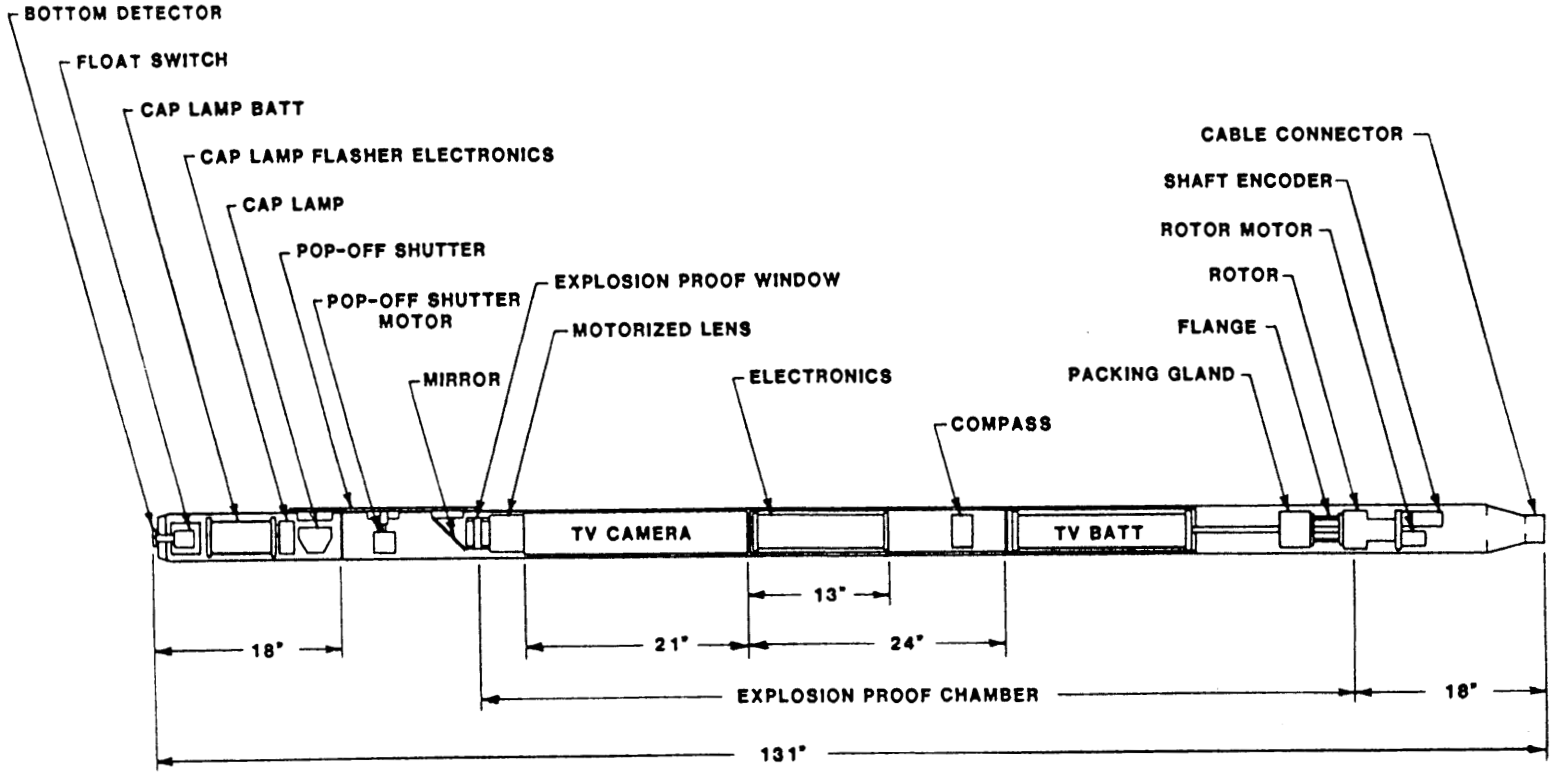

FIGURE 1. PROBE CONFIGURATION

a. Rotor Assembly (See Figure 2) - This unit contains a DC motor, digital shaft encoder, main bearing, and cable connector to attach the probe to the main support cable. In normal operation this assembly remains stationary while the main probe housing suspended below rotates 360 degrees driven by the DC motor. Limit stops are provided to prevent continuous rotation.

b. Packing Gland (See Figure 2) - This assembly provides a protective barrier which feeds cables into the intrinsically safe portion of the probe.

c. Battery Module (See Figure 3) - This area of the probe contains Ni-Cad batteries which operate the TV camera, pan motor, multiplex electronics, shaft encoder and compass.

d. TV Camera/Multiplexer Unit (See Figure 4) - Contained in this module are the multiplex electronics packaged on three printed circuit boards and the TV camera, zoom lens and magnetic compass.

e. Bottom Assembly (See Figure 5) - This assembly contains a bottom detector/float switch, cap lamp illuminator, pop-off shutter mechanism, lamp flasher electronics, batteries and folding mirror which deflects the camera line-of-sight at a right angle to probe longitudinal axis.

Uphole control of the probe is accomplished with a 19 inch rack mount electronics assembly shown in Figure 6. This unit provides digital readout of the compass and rotor (shaft encoder) angles, provides manual controls for the iris, zoom lens, focus and pan motor, and provides three 75 ohm video outputs.

Figure 7 shows the entire systems.

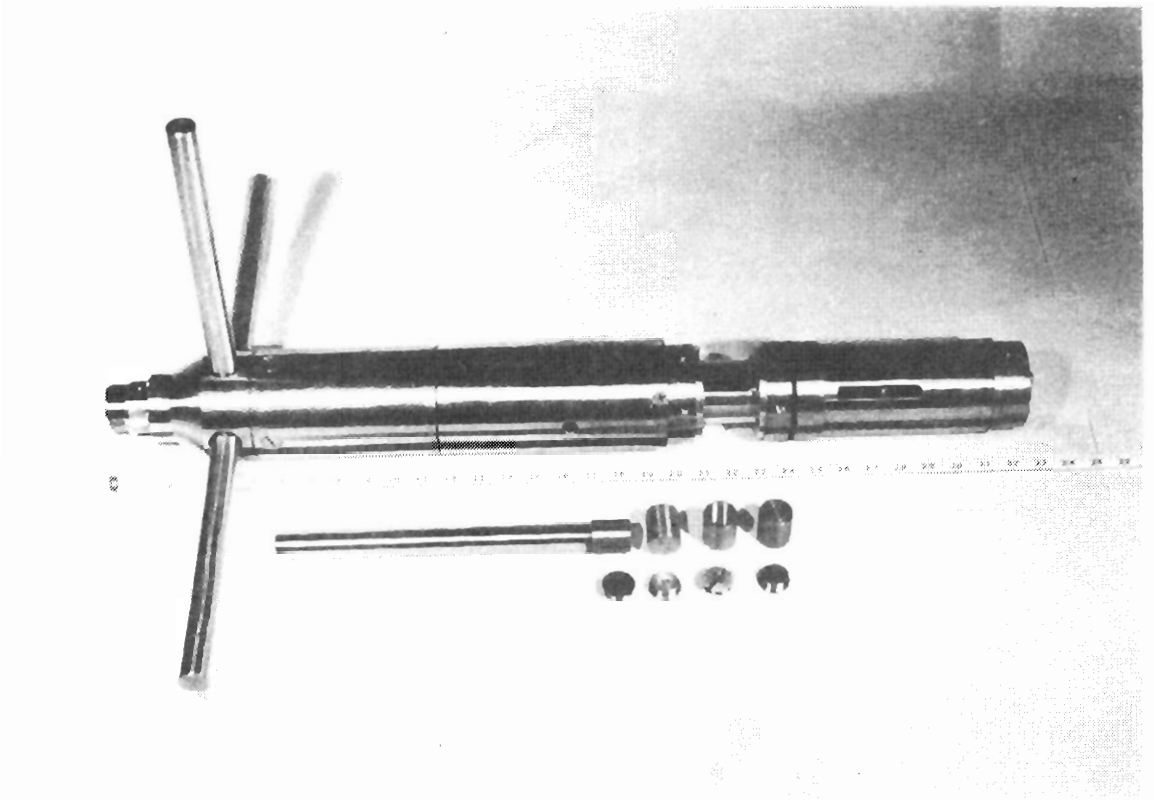

FIGURE 2. ROTOR ASSEMBLY AND PACKING GLAND

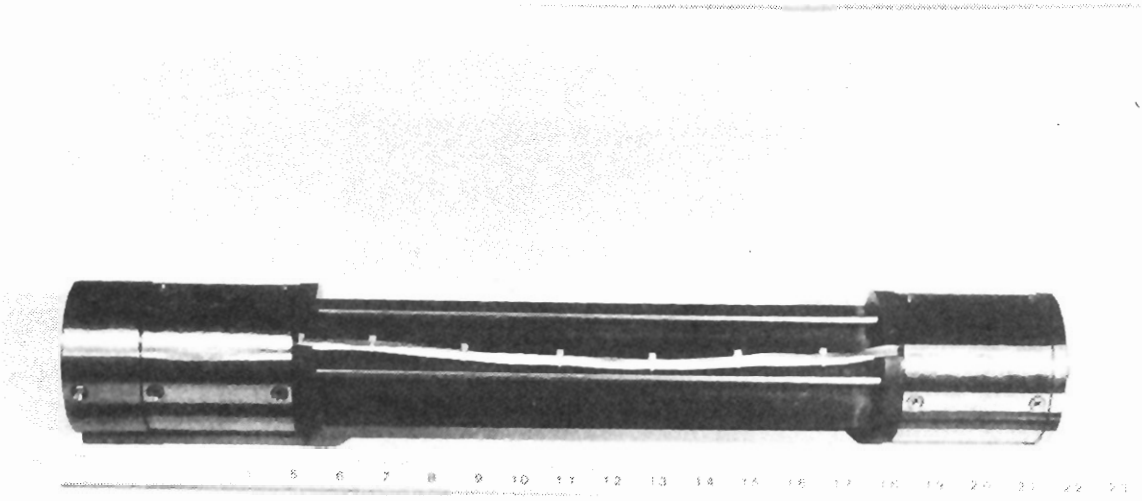

FIGURE 3. BATTERY MODULE

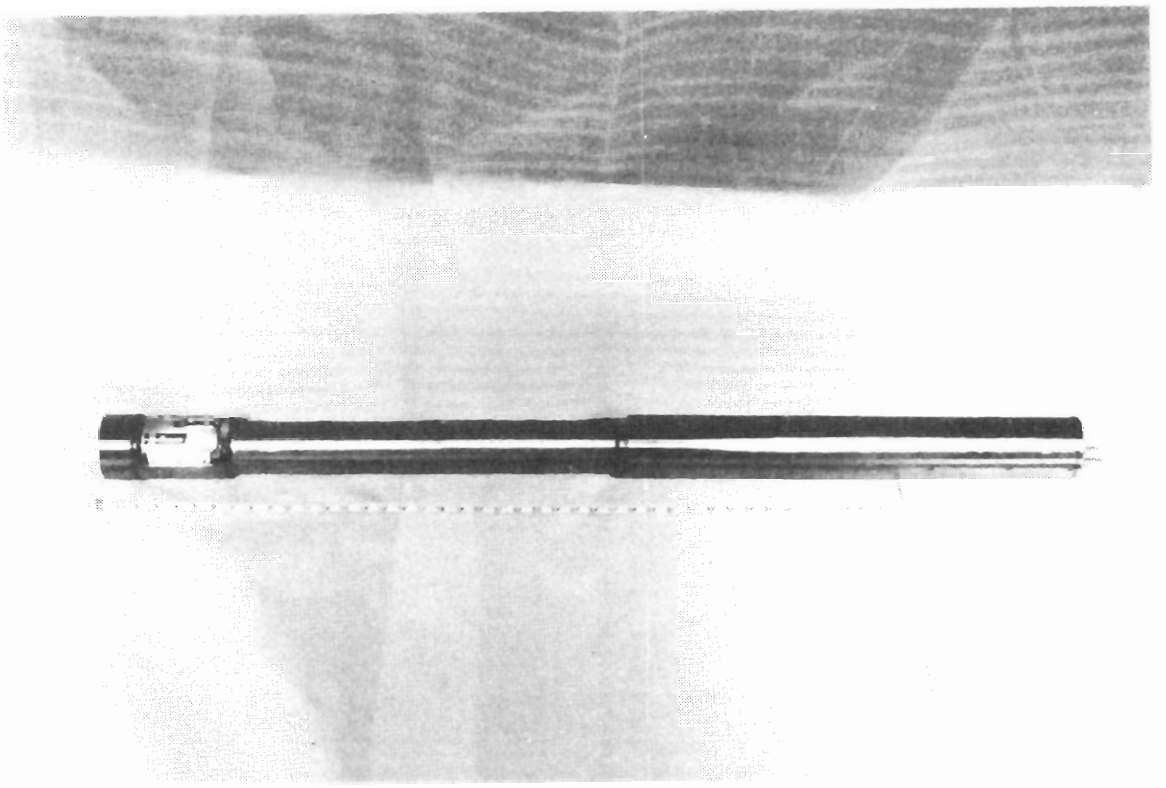

FIGURE 4. TV CAMERA/MULTIPLEX UNIT/COMPASS

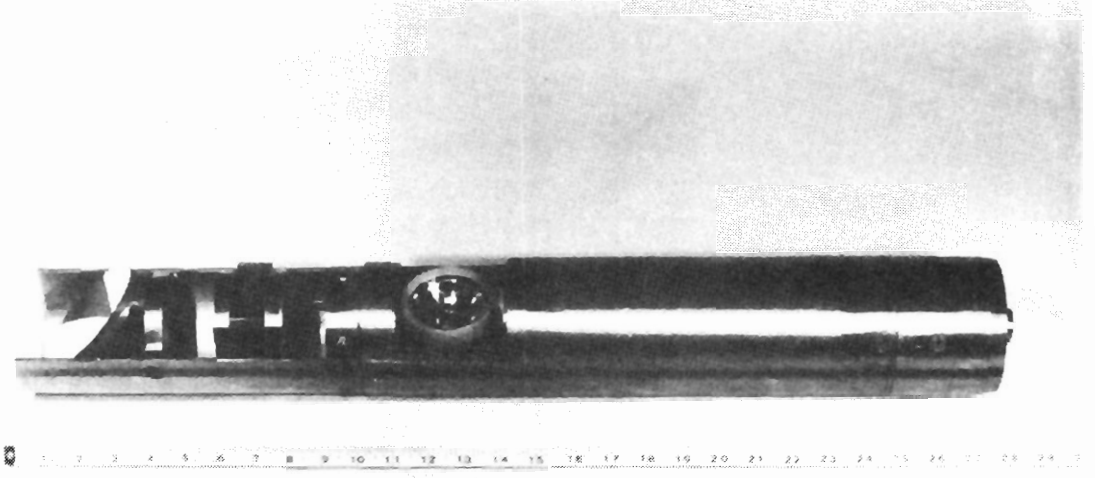

FIGURE 5. BOTTOM ASSEMBLY

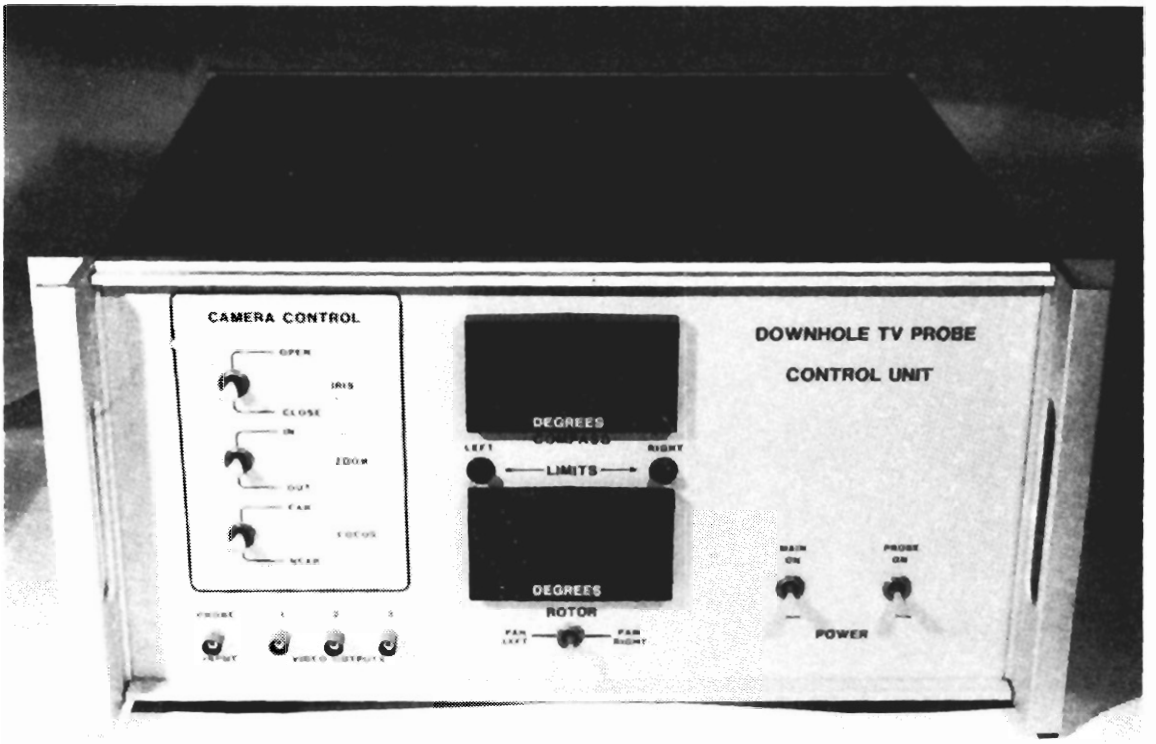

FIGURE 6. CONTROL UNIT

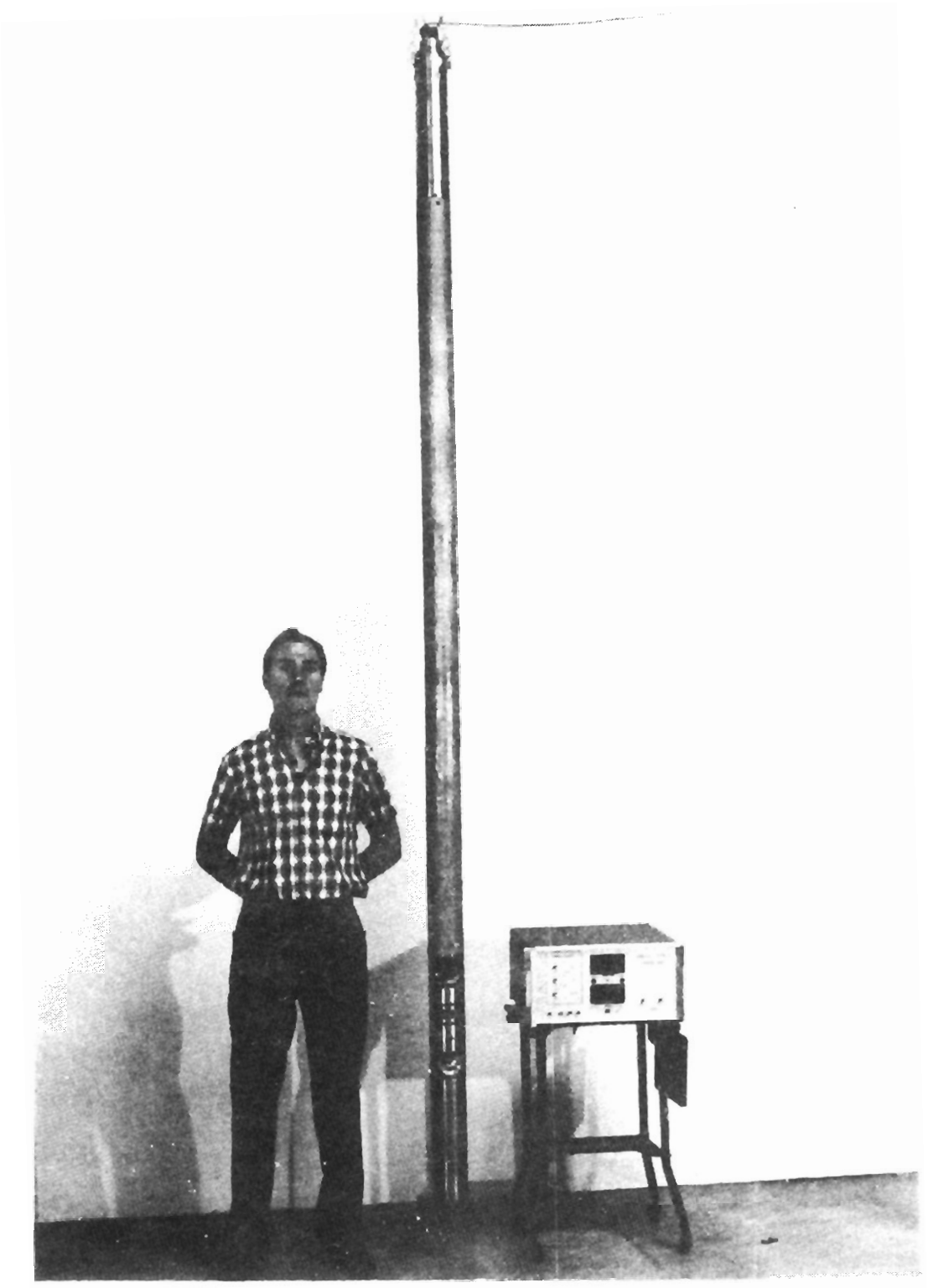

FIGURE 7. CLOSED CIRCUIT BOREHOLE TV SYSTEM

2. TV CAMERA SYSTEM

The TV camera provided by the Bureau of Mines to DEL for use in the probe is a Westinghouse WTC34B-ISIT. This camera contains a one inch intensified silicon intensified tube which provides from 300 to 500 TV lines of resolution at faceplate illuminations of as little as 2×10^{-6} foot candles. It operates from +12 VDC and provides a standard RS-170 composite video output and a separate composite sync output.

The camera's zoom lens is a CANON f2.5 with a zoom range of 18mm to 108mm. The minimum object distance is approximately one meter. The f number is constant throught the entire zoom range. The motors for focus, iris opening and zoom range are located around the peripheral of the lens and use a friction type capstan drive to rotate the lens. Some obscuration of the field of view is experienced at the lower focal range (18mm) due to the limited entrance aperture of the probe.

3. MULTIPLEX ELECTRONICS

Figure 8 is a block diagram of the overall electronic system.

Power for the TV camera is provided through a relay by Ni-Cad batteries within the probe. The relay is energized by a 15 VDC bias signal which is applied to the cable through a 5 kilohm resistor in the uphole electronics. After power is applied to the camera it outputs composite video which is used as the synchronizing signal and clock for both the uphole and downhole electronics.

Figure 9 shows the data format for both the uplink data and downlink data which is transmitted during the vertical interval of the video. Normal RS-170 video is composed of 525 horizontal lines which constitutes a complete frame of video. This frame is composed of two fields of 262.5 lines which are interlaced on the TV screen at a rate of 60 fields per second. For each field there are approximately 20 lines which are blank and do not contain any picture information. These lines do however contain the vertical sync pulse and will always be found at the top of the TV screen in the blanked vertical interval area.

In the system which has been implemented lines 11 through 19 of the first field carry the downlink data while lines 11 through 18 of the second field carry the uplink data from the probe which consists of alternate 8 bit samples from either the compass or the shaft encoder. The data is represented as the presence or absence ("1" or "0") of a high frequency tone burst (approximately 2 mHz) which occupies one vertical line. Descriminators are used to detect the tone bursts and convert to logic levels compatible with the rest of the low power CMOS logic used in both the uphole and downhole multiplex electronics.

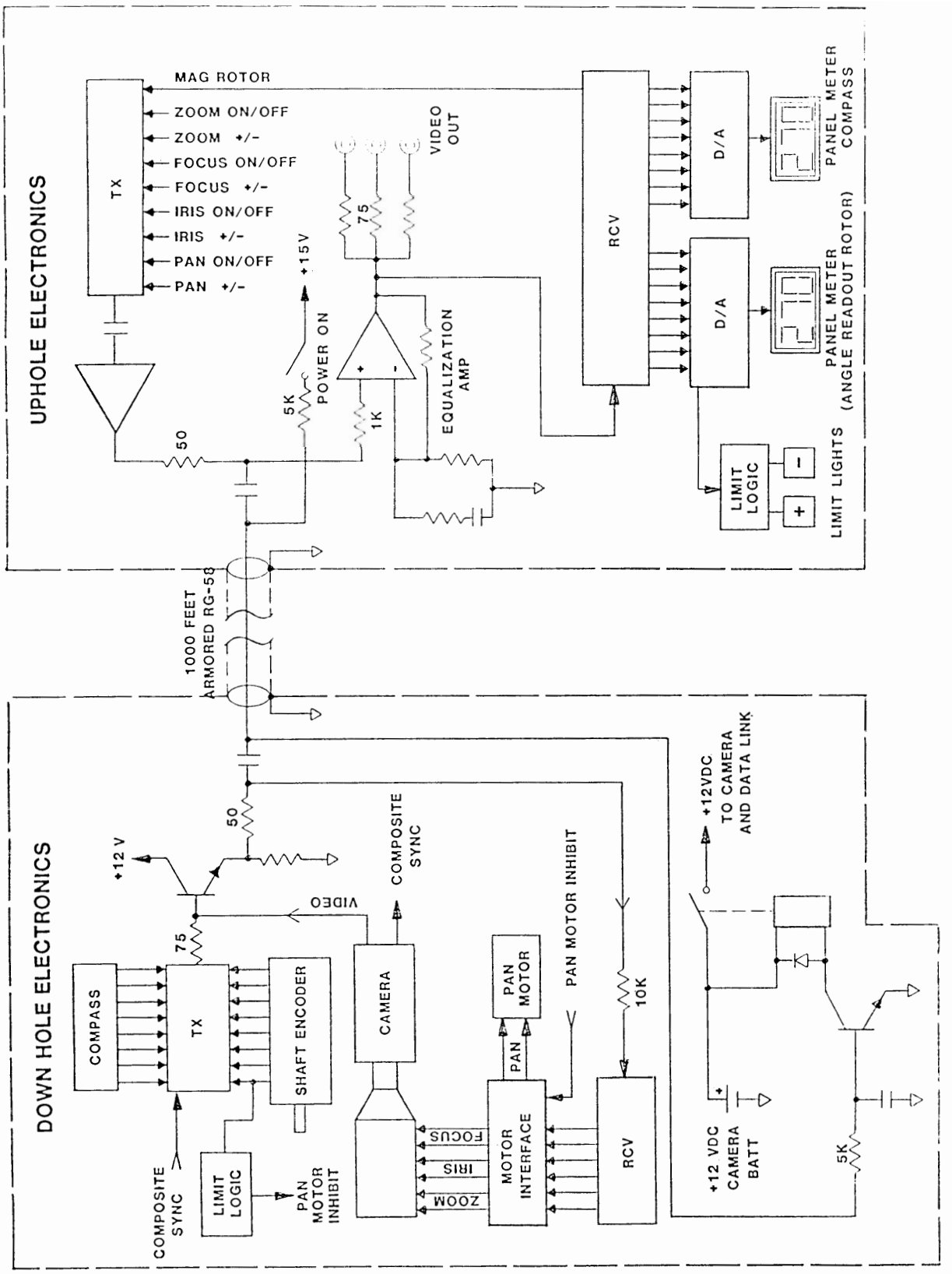

FIGURE 8. ELECTRONIC SYSTEM BLOCK DIAGRAM

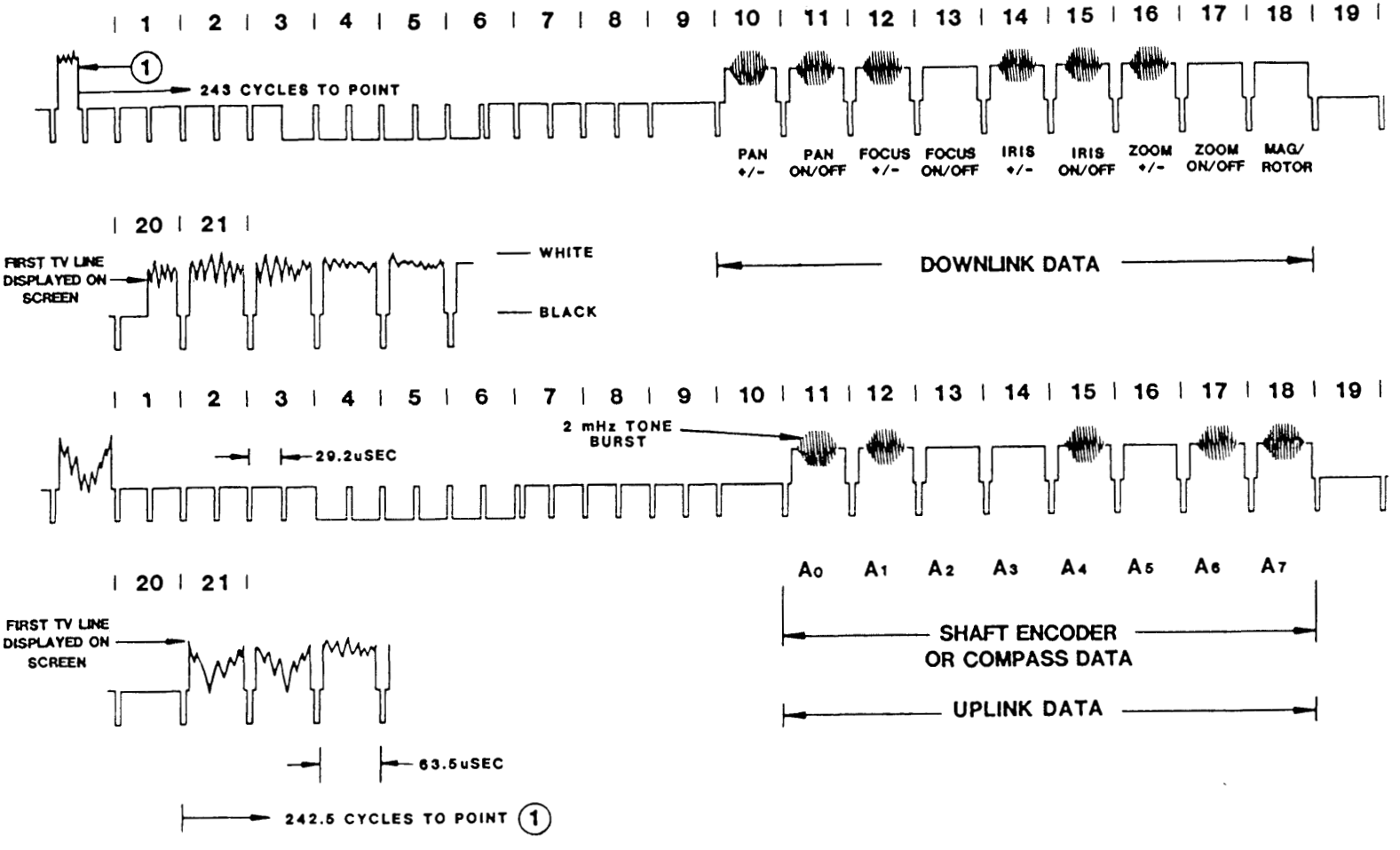

FIGURE 9 . TYPICAL DATA FORMAT

The downlink data is defined as follows:

a. Pan +/-

Determines direction of pan motor rotation.

b. Pan On/Off

Enables or disables pan motor.

c. Focus +/-

Determines NEAR/FAR focus direction.

d. Focus On/Off

Enables or disables focus motor.

e. Iris +/-

Determines OPEN/CLOSE direction of iris motor.

f. Iris On/Off

Enables or disables IRIS motor.

g. Zoom +/-

Determines IN/OUT direction of zoom lens.

h. Zoom On/Off

Enables or disables zoom motor.

i. Mag/Rotor

This is a synchronizing signal which is used to select either magnetic compass data or shaft encoder data to be transmitted uphole on alternate uphole transmissions.

The uphole data consists of 8 bits (A7 through A0) of either magnetic compass data or shaft encoder data which is transmitted alternately during field 2 of each video frame or 15 times a second for each eight bit word. Each of the 8 bit words is converted into an analog voltage and displayon on separate digital panel meters which are scaled to readout in degrees.

4. ILLUMINATOR ASSEMBLY

Downhole illumination is provided by a standard miner's cap lamp which is mounted in the lower portion of the probe below the TV camera. This cap lamp is battery powered from Ni-Cad cells mounted with the lamp. Also contained in this module is a flasher module which causes the lamp to flash for 10 seconds at a one second rate every time a float switch/bottom detector switch is actuated in the bottom of the probe. This notifies the operator that the probe has reached the bottom of the hole or is in water. The flasher circuit is a typical one shot which only actuates once per bottom switch closure permitting the probe to rest on the bottom or in water without flashing the lamp.

When the float switch/bottom detector is first closed a motor is actuated which removes a plexiglass protective shutter which covers the camera's aperture. This pop-off shutter is required to prevent build-up of mud on the camera lens and folding mirror during the lowering of the probe down the borehole.

5. COMPASS

The compass is a Digicourse Model 218 which outputs an 8 bit digital Gray code word representative of the heading. This 8 bit word is transmitted uphole with the multiplexed shaft encoder data.

In the uphole electronics the Gray code word is converted to an 8 bit binary word which is in turn converted to an analog voltage by a digital to analog converter. This analog voltage is scaled and displayed on a panel meter as 0 to 360 degrees.

When the probe is used in cased boreholes or in the vicinity of large amounts of ferrous metals, the shaft encoder is used with known reference points or landmarks to determine camera pointing.

6. ROTOR ASSEMBLY

To maintain compatibility, the same rotor motor manufactured by TRW/GLOBE which was used on the original probe is used on this probe. The rotor section also contains hard mechanical stops to prevent rotation greater than 360 degrees of the probe in the event of an electronic failure. Prior to impacting these mechanical stops electrical deactivation of the motor will normally occur. The circuitry which implements these stops is contained in the downhole electronics and uses the shaft encoder as a sensor to determine when to deactivate the motor. Uphole a similar circuit is used to illuminate a set of panel lamps when either the right or left stop has been reached.

The shaft encoder is manufactured by LITTON and outputs 9 bits of angle information. The normal Gray code angle data is converted inside the encoder to a binary format by an internal TTL circuit. The most significant 8 bits of the data are selected to be transmitted uphole. A digital to analog converter converts this 8 bit parallel word into an analog voltage which is scaled and displayed on a digital panel meter as an angle up to 360 degrees.

7. TEST RESULTS/CONCLUSIONS

Results of test performed at Design Engineering Laboratories showed the LLTV to be remarkably sensitive even under conditions of very low illumination. It seemed to be well suited for the intended application.

The multiplex system performed its task of transferring the data with low drop out or error rate. Its only observed defect was an occassional momentary data drop-out during sudden high frequency transients of the video which could be caused by rapidly covering and uncovering the entire camera aperture with a lens cap. Under normal operating conditions no such problems were observed.

The compass, rotor assembly and cap lamp flasher operated without incident.

The zoom lens mechanism operated properly but required careful adjustment to achieve satisfactory performance. These adjustments consisted of setting the proper tension between rubber drive rings on the lens and the capstan on the drive motors. Too little tension and the lens would not rotate smoothly; too much tension and the motor would occassionally stall. After initially attempting to perform these adjustments with shims, set screws were provided for each motor which provide the required degree of precision to set the tension properly. If the probe is used frequently (i.e. once a day) these adjustments may require attention to compensate for wear of the rubber/capstan drive. At the time the zoom lens was developed no commercially available motorized zoom lens could be obtained which would fit into the 3.5 inch I.D. housing. Late in the program Lennox Instrument proposed a custom direct replacement lens which should be considered as a possible improvement for the existing probe or future versions.